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Summary of Cost and Use Issues

Findings from Chapters 3 through 5 on the adverse side effects of road salt are summarized in this chapter. That discussion is followed by a review of what is known about the effects of calcium magnesium acetate (CMA) as a highway deicer, as summarized from Chapter 6. The chapter concludes with a new section, drawn from findings in previous chapters, covering cost and use issues that must be addressed when considering CMA as a replacement for salt.

ROAD SALT COSTS

Each year about $1.5 billion is spent on highway snow and ice control. Chemical deicing accounts for about one-third of this expense. Sodium chloride, or common road salt, is by far the most widely used deicer, accounting for about 95 percent of deicer treatments. The only other significant deicer is calcium chloride, which is often mixed with salt during colder temperatures. It accounts for about 5 percent of chemical treatments.

Over the years, evidence has grown linking the two most popular chemical deicers—sodium chloride and calcium chloride—with many adverse side effects, including corrosion of motor vehicles and infrastructure, damage to the roadside environment, and contamination of drinking water.

Motor Vehicle and Infrastructure Costs (Chapter 3)

Sodium chloride, as well as calcium chloride, can damage motor vehicles and infrastructure primarily because of the corrosive effects of chloride ions on metals. The chloride ions in salt disrupt natural protective films on metal surfaces and increase the conductivity of water, which induces and accelerates electrochemical corrosion. The best-known side effect of salting is corrosion of automotive metals and rebars in bridges and parking structures. Lesser-known effects, which collectively may be significant, include damage to reinforced pavements and metal highway fixtures; corrosion of underground utilities, pipelines, and steel storage tanks; and degradation of metal objects located on or alongside salt-treated highways.

Motor Vehicles

Motor vehicles have suffered from more severe corrosion since the introduction of road salt following World War II. From the 1950s to the 1970s, the increased use of salt and calcium chloride, combined with the effects of acid precipitation (e.g., acid rain, snow, and dew) greatly increased the corrosivity of the highway environment. The corrosivity of the environment peaked in the 1970s and resulted in widespread rusting of vehicles in the Northeast and Midwest.

During the past 20 years, automobile manufacturers have developed more corrosion-resistant vehicles by improving automotive designs, materials, and manufacturing processes. Improvements include the extensive use of precoated steels, plastics, new primer and coating materials, and modified body configurations that eliminate salt entrapment areas. Today's cars and trucks are less vulnerable to corrosion than vehicles built 10 to 20 years ago. This corrosion protection, however, has increased the cost of manufacturing motor vehicles. On the average, the special materials and coatings used to improve corrosion resistance have added about $500 to the price of a new vehicle.

Only a portion of this expense can be directly attributed to road salt. Other important reasons for protection include acid precipitation, salt spray in coastal areas, and calcium chloride used for dust control. It is likely that even the complete elimination of road salt would result in only partial reductions in corrosion protections and their cost. Estimates by manufacturers suggest that road salt accounts for between one-fourth and one-half of protection costs, or about $125 to $250 per vehicle (0.25 to 0.50 × $500). The total annual cost for the more than 15 million new vehicles purchased each year in the United States is between \$1.9 billion and \$3.9 billion (15.4 million new vehicles × \$125 to \$250).

The primary type of corrosion that persists today is cosmetic corrosion, which is far less damaging than the structural and functional corrosion of the 1970s. Nevertheless, cosmetic corrosion continues to concern motorists in the Northeast and Midwest, where time and money are spent to prevent it and resultant losses in vehicle value and appearance. Preventive efforts include aftermarket rustproofing (which is fast declining in popularity as rust protection during manufacture continues to improve), more vigilant repair of paint damage, and more frequent car washing and other exterior maintenance.

Data are inadequate to reliably quantify preventive maintenance costs or losses in vehicle values due to persistent corrosion. Nevertheless, these costs are likely to be large. A rough estimate to determine an order of magnitude can be developed on the basis of the amount that new car buyers might be willing to spend to eliminate persisting corrosion. If motorists in salt-using regions of the Northeast and Midwest—where 9 million new vehicles are purchased each year—were willing to spend \$125 to \$250 per new vehicle (a plausible range that is equivalent to the cost of existing salt protection features), this cost item alone would be between \$1 billion and \$2 billion per year (9 million new vehicles × \$125 to \$250).

Bridges

The condition of the nation's highways has received intense public and legislative attention during the past 20 years. In the snowbelt states, much of the attention has focused on maintenance and repair problems associated with the use of salt on bridge decks. Salt is especially damaging to decks because the chloride ions in salt, along with moisture, penetrate concrete and cause the rebars to rust, which results in cracking and fragmenting of the surrounding concrete. The damaged areas provide access to additional salt, which accelerates the destructive process. The damage seldom affects the structural integrity of the deck, but it can cause extensive potholing of the deck surface, which can degrade ride quality.

Most decks built within the past 10 to 20 years are equipped with some type of protection to prevent salt penetration and rusting of rebars. Protective systems include waterproof membranes, thicker and denser concrete overlays, and epoxy coating of rebars. To date, deck protection has succeeded in reducing salt damage. However, it has increased the cost of constructing a new deck by about $4/ft^2. Between 20 million and 30 million ft^2 of new deck surface is constructed each year in the Northeast and Midwest; hence, annual spending on deck protection is about $75 million to $125 million ($4/ft^2 × 20 to 30 million ft^2, rounded to the nearest $25 million).

Thousands of decks built during the 1950s and 1960s are now contaminated with chlorides and are deteriorating. Repair and restoration of these decks as they become deficient will be a major expense for many years. However, because they are already contaminated with salt and the corrosive process is well under way, further exposure to salt (or noncorrosive deicers) is likely to have little effect. A more urgent concern is to prevent damage in newer decks that are not already contaminated with salt. Because the many newer decks built during the past 20 years are well protected against salt damage, they should experience fewer adverse effects from road salt than older decks. Even state-of-the-art protection, however, may not completely control corrosion.

A plausible estimate of the number of decks that will become damaged during the next 10 years because of continued salting is 3,500 to 7,000—representing some 25 million to 50 million ft^2 of deck surface. The average cost of rehabilitating a deck is $20 to $40/ft^2. If about 1/10 of the damaged decks must be restored each year during the 10-year period, the total cost will be between $50 million and $200 million per year ($20 to $40/ft^2 × 1/10 × 25 million to 50 million ft^2).

The total cost of installing protection on new decks ($75 million to $125 million) and restoring sound decks that become damaged by continued salting ($50 million to $200 million) will be roughly $125 million to $325 million per year during the next 10 years.

Other components of bridges vulnerable to salt damage include steel framing, bearings, joints, and structural elements made of reinforced concrete. These components can be exposed to salt from leaky decks, faulty drainage, and splash and spray from roadways. The condition of these other components is also affected by factors other than road salt. Compared with deck damage, however, damage to structural elements can be especially difficult and expensive to repair. Although the data available to estimate these costs are limited, the committee believes that collectively they may be as large as deck costs and, as a rough approximation, fall within the same range of $125 million to $325 million per year.

Other Highway Components

Apart from bridges, components of the highway system adversely affected by road salt include concrete pavements, highway drainage systems, and roadway fixtures and accessories (such as metal light stands, signposts, and guardrails). Whereas salt is clearly a factor in bridge durability, its impact on other highway components is incremental and, therefore, difficult to isolate and quantify. Most highway components deteriorate or become obsolete for reasons related to the quality of original construction, maintenance practices, and the environment in which they are located. For instance, important factors affecting durability and replacement of highway fixtures are vehicle collisions, traffic vibrations, vandalism, and functional obsolescence. On the basis of the limited available evidence, the committee believes that salt damage to highway components is sizable but probably an order of magnitude smaller than total bridge costs—totaling less than $100 million per year.

Parking Garages

There are about 5,000 multilevel parking garages in the Northeast and Midwest. Many were built during the 1960s and 1970s, when concerns about salt-related corrosion were minimal. Hundreds of these structures have become contaminated and damaged by salt dropped from parked cars during the past 20 years. The process is similar to that of bridge decks. The chloride ions from salt, along with moisture, seep into the reinforced concrete slabs, reach the embedded steel, and induce corrosion.

Many garages built before the 1970s in heavy salt-using regions are already critically contaminated with chlorides and will need to be repaired (or in some cases demolished) regardless of future salt use. The average cost of restoring a single multilevel garage is about $1 million. On the basis of assumptions about the number of vulnerable garages that were constructed during the 1970s, the committee estimates that between 500 and 1,500 will become damaged by continued salting during the next 10 years. If $\frac{1}{10}$ of these structures must be restored each year for the next 10 years, the annual cost will be $50 million to $150 million (0.10 × 500 to 1,500 × $1 million).

As a precaution against salt damage, many of the approximately 200 parking garages constructed each year in salt-using regions of the United States are equipped with some type of protective system, such as epoxy-coated rebars and a denser and thicker concrete cover. The total cost of installing protection on new parking garages is about $25 million per year. Total parking garage costs from road salt are therefore between $75 million and $175 million per year.

Underground Objects

Corrosion damage to utility lines, pipelines, and steel storage tanks buried under or alongside highways is sometimes linked to the use of road salt, especially in urban areas with a high density of underground utility lines and heavy salt usage.

Most incidents of salt damage to underground objects are reported by water and electric utilities. Newer pipelines and cables are protected from corrosion by special coatings, insulation, or cathodic protection, but salt can damage older lines and other buried equipment, such as transformers, switches, and valve components. Quantification of the damage is difficult because of the presence of other corrosion-causing factors. Corrosion, in general, is a leading cause of failures in pipelines. Pipeline operators and utility companies spend millions of dollars each year monitoring corrosion, applying cathodic protection and special coatings, and repairing corrosion damage. Even if only a small fraction of this spending is related to road salt, the resultant cost could be large.

Another potentially significant, although highly uncertain, effect of salt concerns fuel storage tanks buried under gas station service yards. Corrosion of these tanks has become a major environmental concern during the past 10 years. Thousands, containing petroleum and other hazardous chemicals, have been leaking into surrounding soil and groundwater. Road salt is continually tracked into gas station service yards and is considered one of many factors contributing to the problem. Because removal and cleanup of corroding tanks is expected to cost several hundred million dollars during the next decade, even minor contributions by road salt could have important cost implications.

Roadside Objects

Road salt can adversely affect nonhighway objects located along the roadside. For instance, salt can contribute to the corrosion and degradation of bronze statues, monuments, and copper roofing that are exposed to traffic-generated salt splash and spray. Because the severity and extent of damage depend on local circumstances—such as salt usage, the number of roadside objects, and the presence of other corrosion sources—it is not possible to quantify this damage on a national basis. Salt damage may be significant in some locations, especially if irreplaceable artistic or historic works are involved.

Summary of Motor Vehicle and Infrastructure Costs

The committee's estimate of annual motor vehicle and infrastructure costs from road salt were summarized in Table 3-9. Cost items that can be reliably quantified appear in Category I. Their total suggests a minimum indirect cost ranging from about $2 billion to $4.5 billion per year. Inclusion of other items, for which limited supporting data are available, results in a less precise but more complete estimate of about $3.5 billion to $7 billion per year.

Impacts on the Environment (Chapter 4)

The literature documenting the impacts of road salt on the environment indicates that they can be significant but depend on many site-specific factors, such as the timing and quantity of salt applied, local drainage features, weather conditions, soil type, topography, watershed size, vegetation cover and species composition, and distance from the roadway. In addition, there is likely to be an interaction between salt and other environmental perturbations, such as vehicle exhaust emissions, drought, and plant diseases and pests. Hence, findings from each study must be reviewed in the light of prevailing conditions at the particular site. The only generalization that can be made is that road salt's impacts tend to diminish rapidly with distance from the roadway.

Environmental impacts most frequently cited in the literature are damage to roadside vegetation, soil, and surface water.

Vegetation

Trees and other roadside vegetation, such as shrubs and grasses, can be harmed by salt or other chloride deicers through changes in soil chemistry and splash and spray on foliage and branches. The symptoms of salt injury in trees are similar to those of drought: inhibited growth, browning and falling needles and leaves, and sometimes dying limbs and premature plant death. Under extreme conditions (e.g., high winds), roadside trees can be exposed to salt spray as far as 500 ft from the roadway, although this impact is seldom significant beyond 100 ft. Damage to trees is likely to be greatest along high-traffic highways with heavy salt use and steep, downsloping road-sides. Highway agencies in states where public concern about tree damage is greatest report that 5 to 10 percent of the trees along some sections of heavily traveled highways show symptoms of salt-related decline. Common roadside shrubs and grasses tend to tolerate salt better than do trees, and most states report only minor damage to these plants.

It is difficult to quantify damage to roadside vegetation. Information derived from highway agency interviews and composites of many case studies illustrate the cost of mitigating some of the effects. For example, estimates from state highway agencies indicate that the cost of removing and replacing a damaged tree is $500. Hence, in a 1-mi corridor of highway containing 1,250 to 3,500 trees per mile (within 100 ft of the roadway), in which 5 to 10 percent of the trees must be removed and replaced over a lo-year period, the average mitigation cost would be $3,000 to $18,000 per year (0.05 to 0.10 x 1,250 to 3,500 × $500 × 0.10).

Soil

Salt's effects on soils are usually confined to 15 ft from the pavement. The primary concern is long-term sodium accumulation, which can adversely affect . soil structure characteristics. Specifically, sodium accumulation can increase soil density and reduce permeability, moisture retention,, and fertility, which are important to plant growth and erosion control. However, whether salt has a cumulative effect depends on local conditions, such as soil type, precipitation, and topography.

Where salt severely alters soil structure and reduces essential nutrients, reclamation of the affected soil is an option. The primary objective of soil reclamation is to increase infiltration and moisture retention capabilities. The average cost of reclaiming damaged soil is about $650 per acre. Where soil damage also results in erosion problems, additional erosion control may be necessary. Erosion may be caused by numerous interrelated factors, and the cost of erosion control always depends on circumstances unique to the site.

Surface Water

Salt's effects on surface water are confined mainly to small streams and creeks running adjacent to heavily salted highways. Small receiving lakes and ponds can also be adversely affected, but few such incidents have been reported. In general, salt loadings in larger rivers and lakes are diluted because of high water volumes. In extreme cases, salt concentrations in streams can harm fish and other stream life. The complexity of stream environments, however, makes it difficult to characterize and quantify potential adverse effects.

Summary of Impacts on the Environment

Consolidation of the many site-specific environmental impacts of road salt into a national estimate of salt damage is not possible. Monetary evaluations have been attempted to shed light on the importance of environmental damage. Whereas these efforts have led to increased recognition of salt's effects, they were not intended, nor can they be accurate enough, to compare the overall cost of salt with that of other deicing options. Meaningful estimates of environmental cost can be accomplished only for individual sites by evaluating local circumstances in depth.

Even when environmental damage can be quantified for a specific site (e.g., the number of trees injured along a highway section), a monetary value can be difficult to assign. Estimates of mitigation costs—for example, the cost of removing and replacing an injured tree—provide some cost perspective, but they may be inaccurate or incomplete because they do not reflect the value of the injured tree to society or indirect costs, such as diminished aesthetics and secondary effects on the roadside ecosystem.

Drinking Water and Health Impacts (Chapter 5)

Road salt can enter drinking water supplies by migrating through soil into groundwater or by runoff and drainage directly into surface water. In general, only wells or reservoirs near salt-treated highways or salt storage facilities are susceptible to salt infiltration. Susceptibility depends on many factors, such as salting intensity, soil type, climate, topography, and water volume and dilution. Other sources of salt include natural brines and salt deposits, industrial and agricultural chemicals, and water treatment and softening processes.

During the past 30 years, communities in several states, primarily in the Northeast, have reported higher sodium and chloride concentrations in private wells and public water supplies that have been linked to road salt. Many of these problems have been caused by improper salt storage. Most of the more egregious storage problems are now being corrected. Some communities continue to report salt concentrations in water supplies due to highway surface runoff, although such concentrations are seldom as high as those associated with improper salt storage.

The discovery of higher salt concentrations in drinking water due to road salt has raised concerns about possible adverse effects on public health. Salt is a source of sodium in the diet. Excess dietary sodium has been negatively associated with health primarily because of concerns related to hypertension, or high blood pressure. Typically, drinking water and all other beverages combined (which tend to have much higher concentrations of sodium than drinking water) account for less than 5 percent of daily sodium intake. Because of the normally minor contribution of drinking water to sodium intake, no federal standards have been established for salt (i.e., sodium or chloride) concentrations in water supplies.

Efforts to mitigate the amount of salt in drinking water vary by state and community. Mitigation may include modification of highway drainage, relocation of private wells, upgrading of storage facilities, and reduced salting near water supplies. Nationally, about $10 million is spent each year on mitigation by state and local governments, mostly in the Northeast and Midwest.

CMA

In 1980 the Federal Highway Administration (FHWA) identified CMA as a potentially suitable replacement for salt. Numerous laboratory and field studies have been conducted during the past decade to evaluate its field performance, environmental and health effects, compatibility with automobile and highway materials, and production cost. Findings from completed studies and interviews with CMA field users are summarized in the following sections.

Field Experience

Although reports are not always consistent, experiences of CMA users provide some general insights into CMA's field performance